



Opportunities in Land Mine Warfare Technologies

The Self-Healing Minefield



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The Future of Obstacles



- **Future obstacle systems must be compatible with the transformed Army**
 - **Obstacles will contain**
 - Integrated networks
 - Artificial intelligence
 - Autonomous operation capabilities
 - **Obstacle must have variable responses/functions**
 - Full spectrum – Non-lethal to lethal
 - Role in all contingencies
 - Intelligence gathering
 - **Obstacle should be a maneuver force multiplier**
 - On-Demand and organic
 - Extended emplacement range
 - Robotic delivered
 - Reduce logistics burden
 - Controlled by maneuver element





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The Future of Obstacles

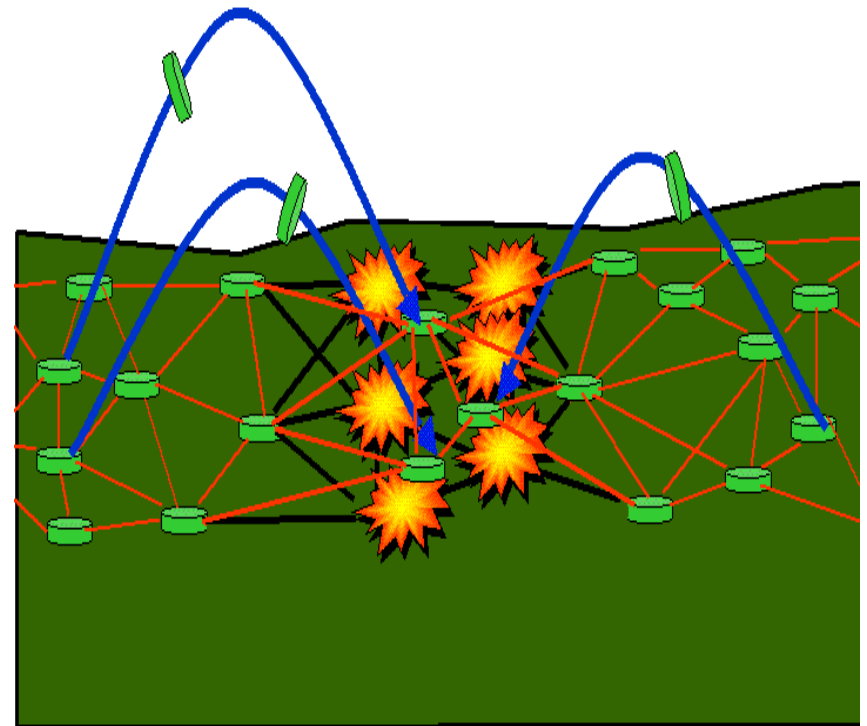


- **Future obstacle should permit for increased control**
 - **Moveable/reconfigurable via command or autonomous behavior**
 - Offensive
 - Defensive
 - **On-Off capability**
 - **Self or command neutralization**
 - **Discrimination of targets**
 - **Identification of friend or foe**
- **Extended operational space**
 - **Area denial to volume denial**
- **DARPA is developing some key enabling technologies for future obstacles**
 - **Self-Healing Minefield**





- The Self-Healing Minefield provides a robust obstacle complicating both mounted and dismounted breaching **without the use of antipersonnel landmines**
 - An antipersonnel landmine alternative for the mixed system
- The Self-Healing Minefield Concept
 - Minefield is deployed and begins autonomous monitoring of obstacle integrity
 - Minefield detects a breach attempt via mine-to-mine communication
 - Minefield autonomously determines vulnerability and appropriate response
 - Individual mines respond by reorganizing (moving) to fill breach re-establishing obstacle



Minefield acts like a fluid - cannot sustain a breach





Technical Goals & Objectives



- **Goals**

- Develop and demonstrate the enabling technologies for an intelligent, mobile antitank mine system
 - Minefield must autonomously identify and respond to a breach within 10 seconds

- **Objectives**

- 7-10 meter movement of a 2 kg prototype mine **(current size)** within 10 seconds
 - Movement can be single or multiple hops
 - Resistant to multiple breach attempts
- Rapid assembly of a scalable communication network
- Non-GPS based geolocation with 1 meter location accuracy
- Decentralized determination of breach vulnerability and appropriate response within 10 seconds
- Demonstration of functionality and breach response of a 50+ prototype minefield
 - Mobility
 - Communication
 - Behaviors
- **Investigate opportunities for smaller mortar launched version of mine**





Technical Challenges



- **Mine mobility**

- Compact multi-hopping system
- Two sided mobility or single sided mobility with self-righting
 - Must operate in complex terrain
- Directional control and repeatability

- **Inter-mine communication**

- Compact self-organizing network scalable to 1000 nodes
- Relative battlefield geolocation to 1 meter without using GPS
 - Acoustic ranging
- Pathway to low probability of jamming/spoofing network

- **Minefield healing algorithms/behaviors**

- Detection and localization of breach
- Robustness against enemy communication and mobility countermeasures
 - Systems must degrade gracefully
- Differentiation between minefield disturbance and breach
 - Minefield anti-tampering





Self-Healing Minefield System Concepts



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Full Self-Healing Minefield



- **Antivehicle landmine system emplaced using current doctrine**
 - Same size and weight as Volcano mine
 - Compatible with current emplacement systems
- **Complete autonomous operation once emplaced**
 - Obstacle enhanced by covering fires
- **Lifetime up to 30 days**
 - Opportunity to reset self destruct time for extended lifetime
- **Complex minefield behaviors possible to add versatility to obstacle**
 - Delayed healing times to segment or trap enemy vehicles
- **Pathway for external control after emplacement**
 - Networked mine system with network based health monitoring of mine and communication for positive control
 - Long-haul nodes interspersed to provide reach-back/forward





Precision Obstacle On-Demand



- **Tactical minefield for a maneuver element**
 - Reduced size Self-Healing Minefield
 - Assures decreased logistics burden
- **Standoff emplacement**
 - Organic to Battalion or below to assure timeliness
 - Placed rapidly, accurately and on-demand during an engagement by engaged element
- **Deployed organically**
 - Pre-planned not necessary
 - Laid in close proximity to enemy forces or maneuver elements
 - Reduced minefield deployment timelines
- **Used for both offensive and defensive actions**
- **System would be deployed only **where** and **when** necessary to reduce total number of minefields required**



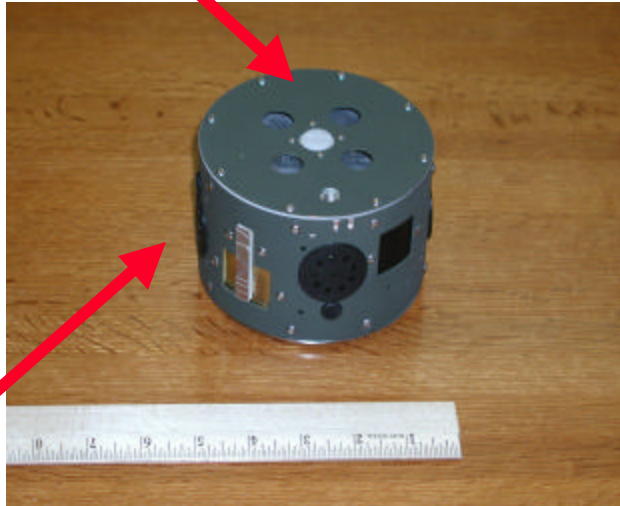


System and Technology Development



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Top & Bottom mobility/SAF



Communications unit

- Battery
- 2 FHSS radios
- Orientation sensor
- GPS
- Acoustic board
- Processor
- 4 speakers/microphones

Preliminary mine design

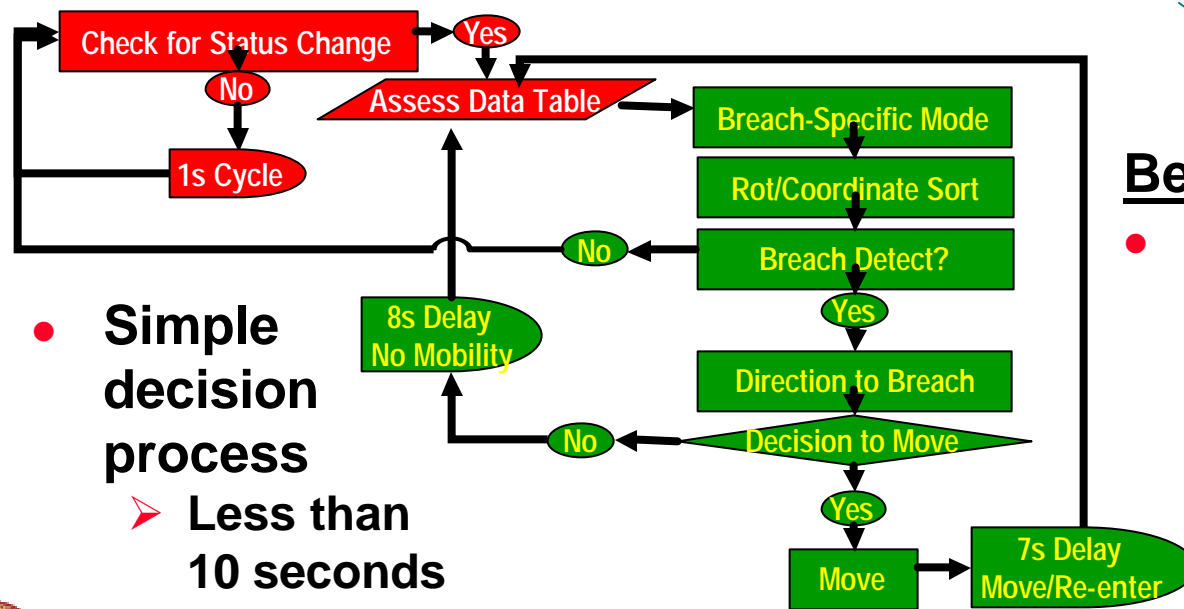
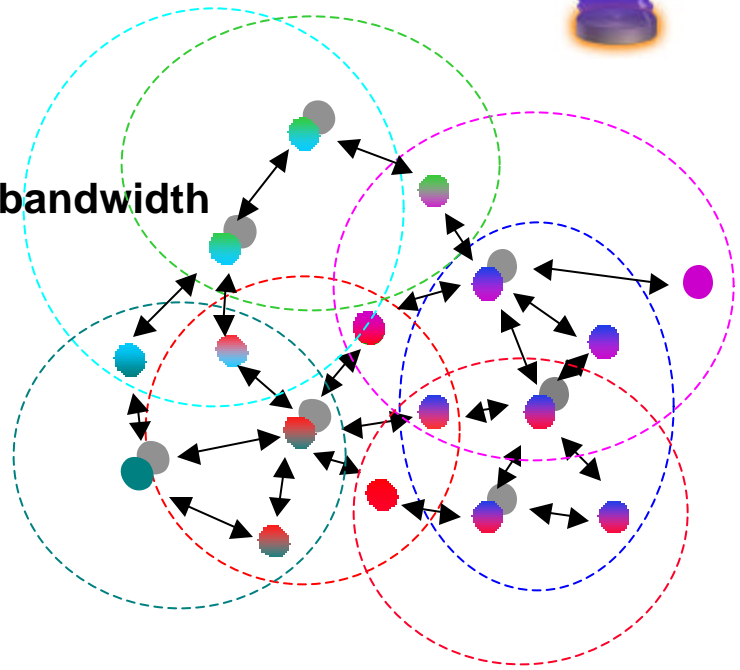
- 12 cm diameter
- 7.2 cm height
- Less than 2.5 kg
 - Volcano = 2 kg
- Electronics and battery volume reduction to fit warhead

Locomotion

- End mounted rocket thrusters
 - Clearing charge necessary
- Double sided mobility
 - Requires two sided warhead
- 4 thrusters per side
 - 25 N-s impulse
 - 100 ms action time
- 9 meter range
 - 3 meter max height

Communication/Networking

- Frequency hop spread spectrum
 - 2.4 GHz center with 83 MHz bandwidth
 - Tactical system – different frequency and bandwidth
- Acoustic ranging
 - Sub-meter location accuracy
 - Secondary communication channel
- Self-organizing network
 - Rapid assembly and scalable
 - Dual modem architecture



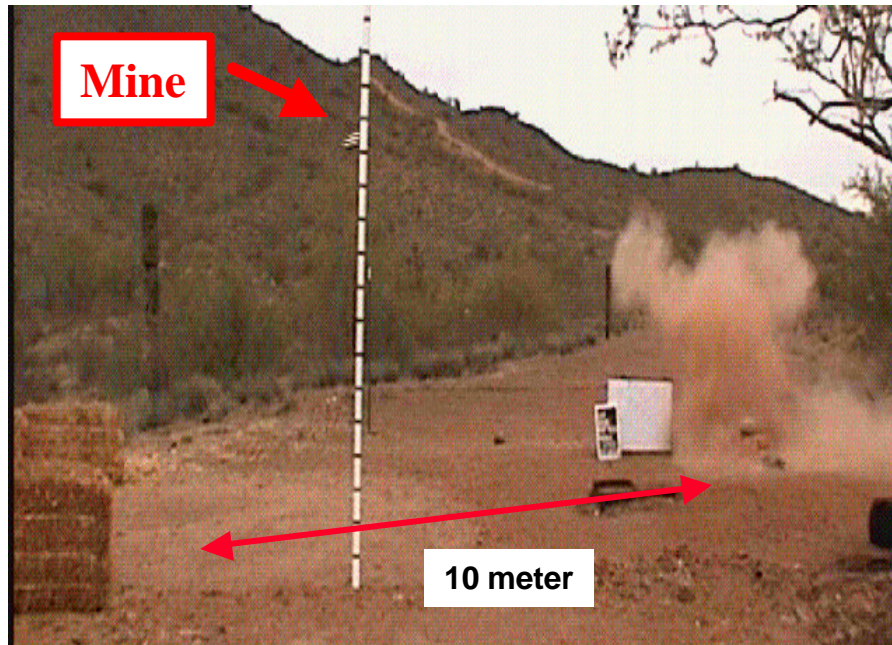
- Simple decision process
 - Less than 10 seconds

Behaviors

- Multi-mode reorganization algorithm
 - Breach specific
 - Nearest neighbor
 - Random
- ↓ Less Info.

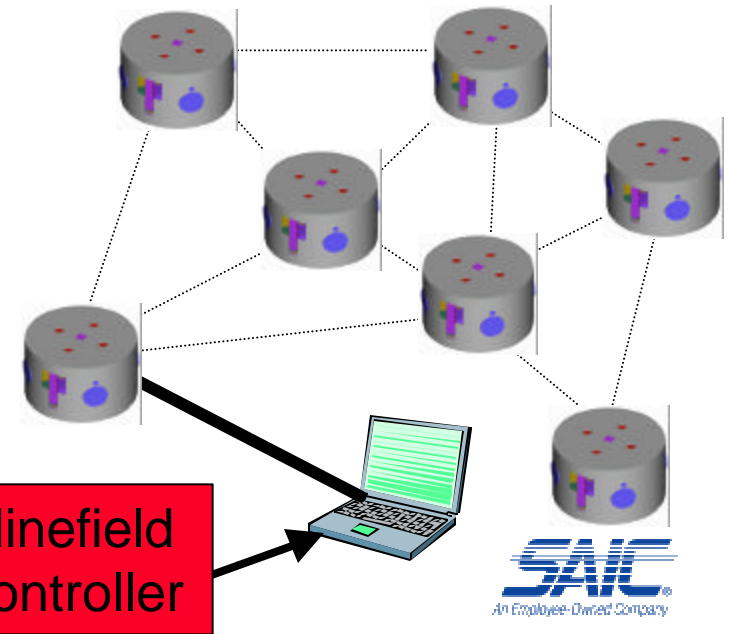


SAIC - Current Status



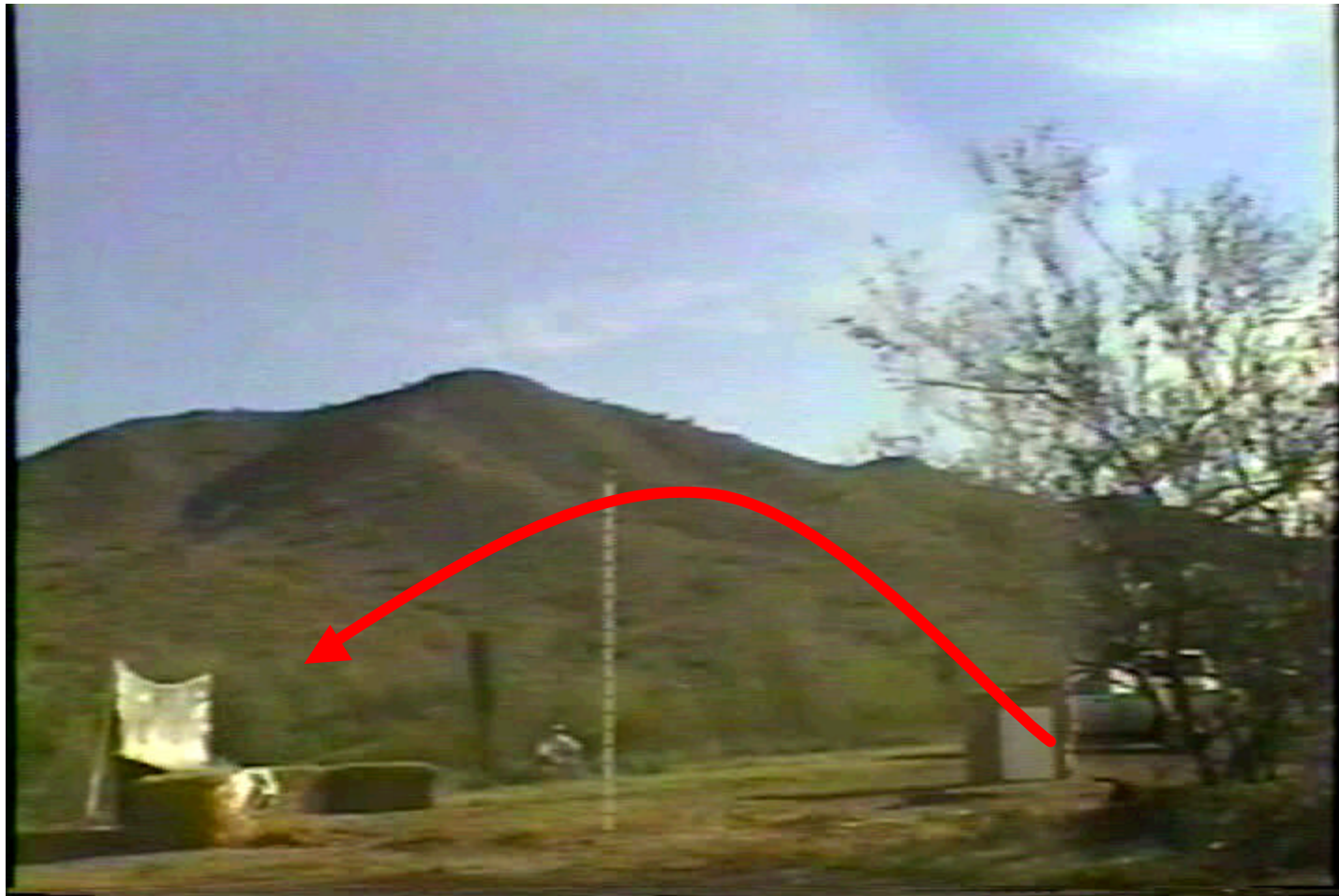
- **Single thruster prototype tests**
 - Under center of gravity thrust for robustness on various ground planes
- **System performance demonstrated**
- **10 mine system test March 2002**
validated breach detection and mobility response (up to four mines hopped)

- **Demonstrated ten prototype communication units**
 - Rapid network assembly
 - Node disappearance, appearance and disturbance





SAIC - Recent Flight Test



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Sandia - Concept

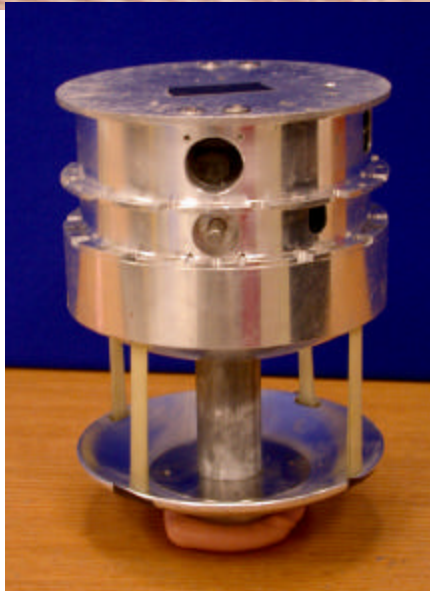


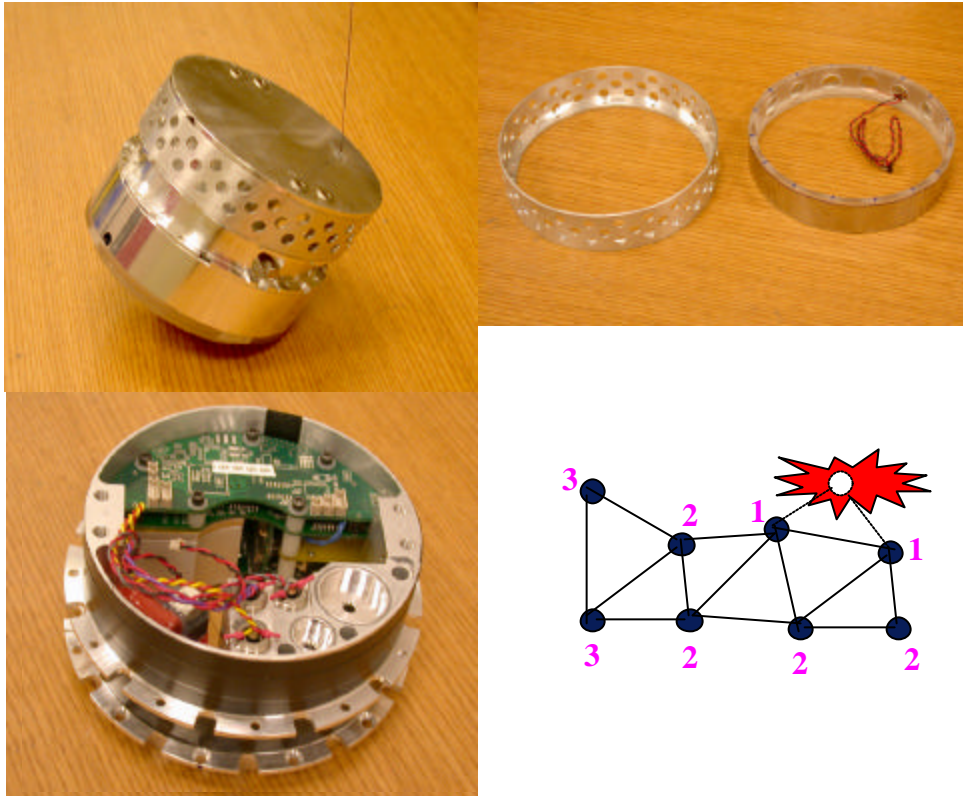
Preliminary mine design

- 12 cm diameter
- 11 cm height
- 2.0 kg
- Carries simulated warhead

Locomotion

- Piston based - ground impact
 - Fuel/oxidizer
- 3 to 5 meter jump height/range
- Single-sided/self-right
- ~100 Jumps with onboard fuel
- Tested in different soils
 - Sand
 - Peat moss
 - 8 p.s.i. Mud
 - Buried



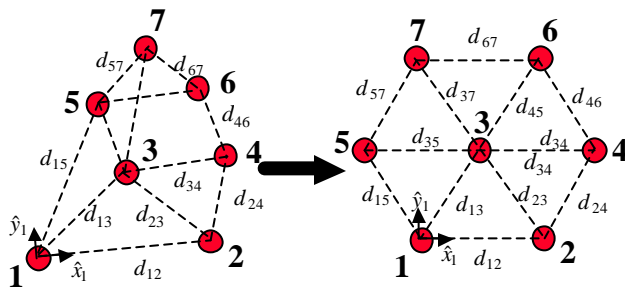


Communication/Networking

- 900 MHz COTS chipset
- Acoustic ranging for relative geolocation
- Self-organizing network

Behaviors

- Rule based/potential energy method
 - Local environment
 - Decentralized
- Minimization with repelling constraint
 - Fictitious force
 - Decentralized
- Both focus on in-lane healing





Sandia – Recent System Test



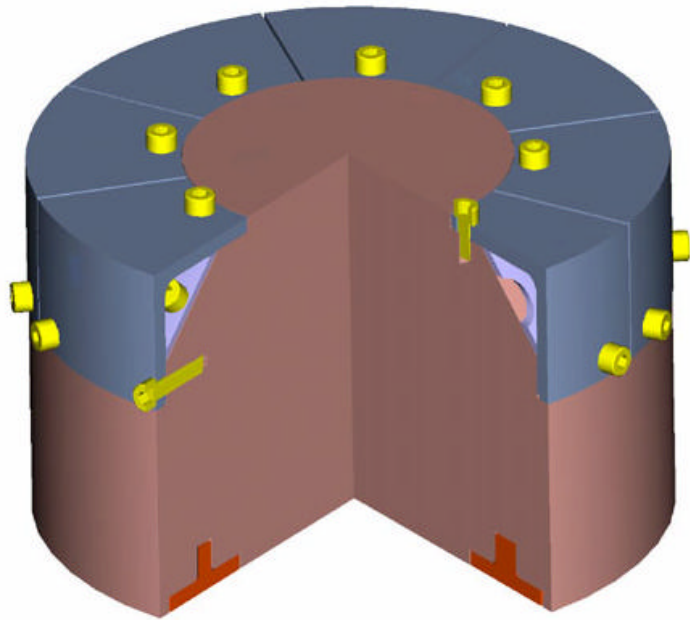
- Breach response validated using 5 static and 5 mobile mines



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Foster-Miller - Mobility System



- **Pyrotechnic based mobility**
 - Small, simple, electrically initiated charges/squibs
 - Expels fly plate
 - Range - 10+ meters per jump
 - Demonstrated 100 meters
 - Lower shock approach under investigation
 - Goal of less than 10 kGee
- **Multiple charges 8-12**
- **Reduction of size for Obstacle On-Demand**



 Foster-Miller





Foster Miller – Flight Tests



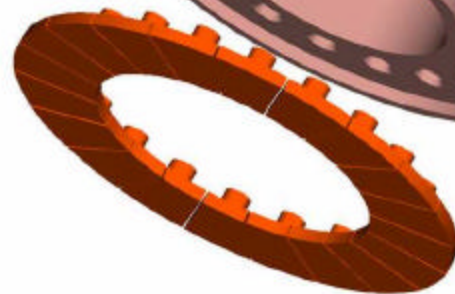
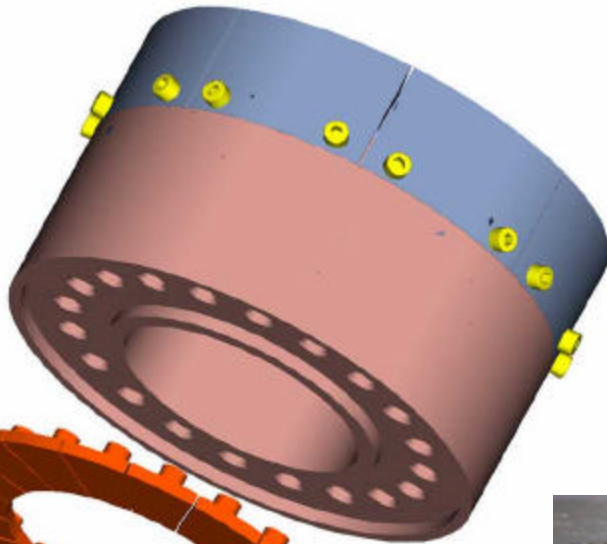
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Foster-Miller - Self-Righting




Hopping
charges



Self-righting
charge ring

- **Smaller charge for self-righting**
 - Small single direction warhead
 - Reduced weight
- Initial field test results show better than 50% chance of success per charge**
 - Up to 24 charges per mine
 - Eliminates edge resting mines

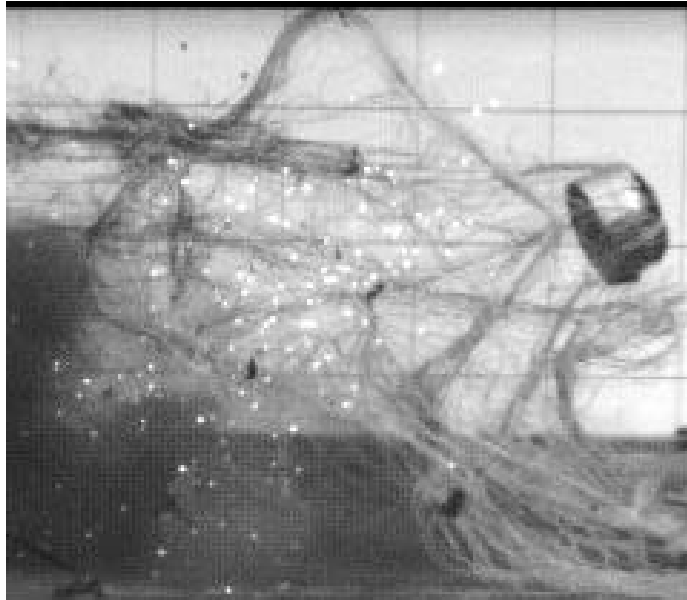


 Foster-Miller





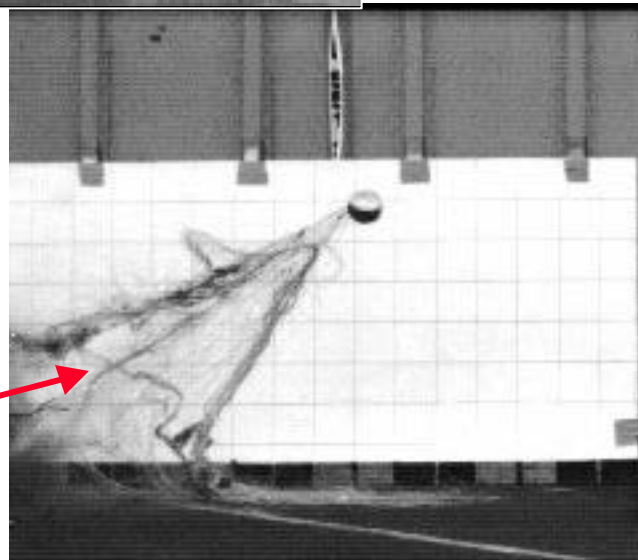
Foster-Miller - Countermeasures



- **Mobility countermeasures investigated**

- **Net systems of various sizes, mesh densities, weights, deployment methods**
 - Mine breaks free or drags net
- **Physical impediments placed on mine**
 - First hop frees mine permitting additional hopping
- **Buried in up to 5 inches of sand**
 - Mine extracts itself

Net dragged with mine



 Foster-Miller





Self-Healing Minefield Control



- **Self-Healing Minefield can be linked to commander via reach-back capability**
 - Determine location of enemy breach and call for fires at that location
 - Relay enemy vehicle information and breach vulnerability
- **Self-Healing Minefield can be designed to permit control at appropriate levels**
 - On/Off/On and command destruct enabled by network heartbeat and status monitoring
 - Requires all mines to be part of the network assuring communication link
 - If mine drops off network it hops to change RF environment
 - After multiple hops mine will self destruct if network link cannot be established





Self-Healing Minefield

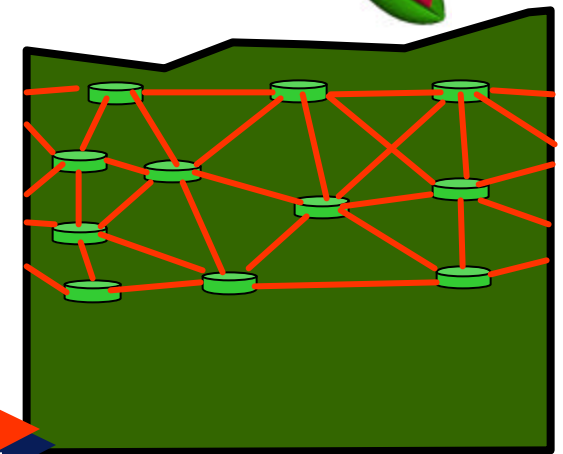
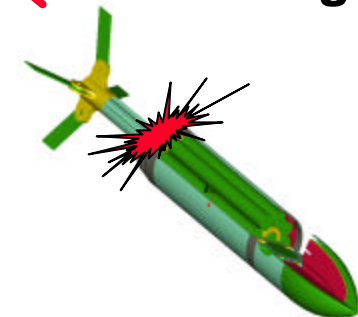
Precision Obstacle On-Demand



Precision Obstacles On-Demand



- Small, mobile (intelligent?) antivehicle mine that can be emplaced using 120 mm mortar or other carrier system
 - Exploits technical successes in Self-Healing Minefield program
 - Miniaturized warhead
 - Compact, self-righting mobility systems
 - Leverages Army development including novel extended range 120 mm mortar cartridge – XM984



Rocket Assist Extends Range to 11 Km





POOD Mine Characteristics



- **Novel antivehicle mine characteristics**
 - Less than 1 kg
 - 10 cm diameter & 5 cm thick
 - Up to 12 ten meter hops per mine
 - Provide dynamical antivehicle minefield
 - Lifetime of minefield short
 - Minimal wait between emplacement and encounter by enemy
 - Self-Destruct/Self-Deactivation
- **Additional potential capabilities**
 - Full networked system architecture
 - Identical to larger sized Self-Healing Minefield capabilities
 - Integrated minefield reach-back/reach-forward
 - Minefield control (on/off/on)
 - Status updates
 - Command sanitization





Technologies Needed



- **Mine mobility**
 - Continued miniaturization of pyrotechnic hopping concept being investigated for the full Self-Healing Minefield
 - In-depth investigation of single-sided mine variant required
- **Warhead**
 - Miniaturization of warhead under investigation for current Self-Healing Minefield
 - Focus on crew kill rather than multimode (crew and track kill)
- **Standoff emplacement system**
 - 120 mm mortar cartridge or other
- **Tactical and system modeling**
 - Investigate doctrinal opportunities
 - Evaluate minefield effectiveness
- **System evaluation**
 - Investigation of opportunities to incorporate intelligence and communication capabilities





Conclusions



- The Self-Healing Minefield will prevent/impede a successful breach of an antitank minefield **WITHOUT** antipersonnel landmines
 - Assures a robust obstacle to disrupt enemy vehicles
- Small antitank mine and novel standoff emplacement permits precision on-demand deployment of obstacles consistent with future combat doctrine

